CEMENT AND LIME MANUFACTURE

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Iron and Steel in the Cement Industry.

THE production of Portland cement in Great Britain now amounts to about eight million tons per annum, which calls for the use of about fourteen million tons of raw material and two million tons of coal. The power used is almost all transmitted electrically and the consumption amounts to some 600 million units per annum, most of which is used for grinding or equivalent purposes either in the preparation of raw materials or coal or the finishing of the product. These processes involve continuous abrasion of both the charges and the linings of the mills. There are also many auxiliary processes, especially in connection with the winning of the raw materials, in which the wear and tear is considerable.

The wear on iron and steel is therefore of considerable importance in every cement works. It is probably true to say that the consumption of steel amounts to about 4 lb. per ton of product ; this means a total of 14,000 tons per annum. Most of this steel is of a special nature or has special properties, and would probably cost on the average from £18 to £20 per ton. Taking the mean figure, the value of iron and steel used per year in the various processes would amount to a total of, say, up to £275,000. The purpose of this article is to review in a general way the characteristics of various materials involved.

It may be stated first that steel can be manufactured or heat-treated to possess any desired characteristic. It may be made very hard or soft ; it may have a very hard surface with a soft core ; it may possess an amount of resilience or it may be the opposite, i.e. lifeless. It may initially be soft or malleable and attain a work-hardened surface as soon as wear takes place. It may possess a non-rusting or non-corroding property ; it may also be resistant to the effect of heat, that is to say, it will not oxidise or deteriorate, or at any rate the amount of oxidation or deterioration will be very low even if it were kept at a high temperature for a long period. Although steel can be manufactured to possess

any one or more of the characteristics named, ordinary steels cannot be made to possess a combination of conflicting characteristics. Some alloy steels go a long way towards bridging this gap, and can be manufactured to possess double and to some extent conflicting characteristics though to a limited extent.

Dealing with the matter in detail it appears best to consider the characteristics of various kinds of steel and review these characteristics in relation to the duty in which they have given satisfactory or unsatisfactory service. When it is possible to associate a standard specification with any steel a reference will be made to such specification.

Teeth of Excavator Buckets.

The renewable teeth fitted to excavator buckets are subject to severe duty. Manganese steel has proved very suitable for use in limestone and other such hard materials. It, however, has proved definitely unsuitable for the softer materials. Oil toughened carbon steel has proved the best and most suitable for chalk and some softer materials, but is of no use for limestone and the hard materials. This apparently conflicting experience indicates that the duty in chalk and the softer materials is so light that the amount of " work hardening " on the surface of the manganese steel is not sufficient to bring out the most valuable characteristic of this material.

Manganese Steel.

Manganese steel possesses some very remarkable properties. Chief among these is an extraordinary combination of high tenacity and toughness. As cast, this steel is comparatively brittle and annealing is necessary. The annealing process consists of heating to about 1,000 deg. C. and quenching in water, a treatment which would render ordinary steel intensely hard and brittle.

Manganese steel, as used, also possesses extraordinary resistance to abrasion and it is this characteristic which has rendered it of such great service under heavy wear conditions. A Brinell hardness number of about 200, as obtained in the annealed condition, affords no explanation of its wearing qualities. The explanation is that under the pressure of impact or any abrading action the surface hardness figure increases from about 200 up to 500 or even 600 Brinell ; at the same time the condition of the metal underneath the face retains its extraordinary toughness. Moreover, as the surface becomes worn away under the abrading action, the newly-exposed metal becomes similarly hardened and the wear-resisting surface is automatically renewed, hence the great advantage of this steel for wearing parts.

Manganese steel is used almost exclusively for the wearing parts of all kinds of crushing machinery, i.e. false faces and toggle seatings for jaw crushers, mantle and concave parts of gyratory crushers, sleeves for roll crushers, hammers and breaker-plates for hammer crushers, as well as for all types of lining plates. It can with confidence be used for the following parts of other machinery, such as crawler track shoes, links and pins for the power excavators, pins and links for many types of conveyors and elevators, elevator buckets, plates and scrapers for scraper conveyors, etc.

To summarise, manganese steel, cast or forged, is a high tensile, unbreakable, and very malleable material, and provided the duty produces " work hardening " it will give extremely good service under the most severe conditions. The malleable characteristic, with a resulting tendency to spread under impact conditions, must be provided for in the design. Although the composition of manganese steel follows well-defined lines, purchasers and users of this material would be well advised to consult well-established manufacturers on any new design or even old designs which have proved troublesome owing to the different effects brought about by varied heat treatment.

Mill Linings.

Mill linings are subjected to the percussive action of large balls, etc.; with small balls the severity of impact is much reduced, but the impact effect remains. Chrome steel and manganese steel are equally suitable for this duty if the design of the lining is correct. Manganese steel, owing to its malleable characteristic mentioned earlier, tends to spread on the hammered surface; this tendency is not noticeable, or in any case it is not serious, in the case of chrome steel. Chrome steel is almost immune from rust and oxidation, and is therefore specially suitable for wet grinding conditions. If the design of each lining is suitable for its own material, and if the castings are correctly heat-treated, there is good reason for anticipating equally good service under dry conditions for both chrome steel and manganese steel. Under wet and comparable conditions chrome steel should prove definitely the best. Either material, however, will demand a good bed of grit in the respective chambers to reduce metal-to-metal contact and impact as much as possible.

Lining of cast iron is suitable for dry conditions when the diameter of the balls or media is not greater than, say, 1½in. The iron should be " white," toughened with, say 20 per cent. of good mild steel scrap; the amount of scrap usable will depend on the general " mix." The hard and polished surface of an iron lining will encourage slipping and the surface of the lining should be made irregular or uneven to counteract this tendency.

Grinding Media.

Media for dry grinding should be of the hardest material possible consistent with toughness. Forged steel for all balls above 1½in. diameter has definitely proved the most reliable and best. The carbon content should be, say, 0·6 per cent. to 0·75 per cent. If manganese were added to the extent of 0·7 per cent. to 0·8 per cent. improved toughness will be obtained. Carbon and high silicon steel such as are used for railway metals have also proved very satisfactory for milling conditions. It should be stated, however, that the service usually obtained from forged balls is very erratic owing to the use of short ends, etc., of more or less unknown composition.

Media of 1½in. to ¾in. diameter may be of toughened " white " cast iron. Media of smaller dimensions than this may be of short cylindrical pieces cropped from rolled steel bars of high carbon steel and having a length about equal to

or slightly greater than the diameter. Usual and standard dimensions for this media are $\frac{3}{4}$in. by $\frac{3}{4}$in., $\frac{5}{8}$in. by $\frac{5}{8}$in., $\frac{1}{2}$in. by $\frac{1}{2}$in. and $\frac{7}{16}$in. by $\frac{7}{16}$in. These pieces, after cropping, should be heated above the critical temperature and immersed in water or oil for hardening. Th ‹carbon content of the steel will determine which liquid should be used.

For wet grinding the large media (1$\frac{1}{4}$in. and above) should be similar to that used for dry grinding. The smaller media, however, should be of high carbon steel bar, cropped and hardened as mentioned. Pieces $\frac{3}{4}$in. by $\frac{3}{4}$in. are the smallest size that can be used economically under wet conditions owing to rapid waste.

Shafting.

Shafting plays an important part in works equipment, and owing to the higher stress at which most machinery now works nothing less than the best or at any rate nothing but the most suitable, should be used for driving shafts.

Short shafts for mills of all kinds and for kiln driving gears should all be of oil-toughened forged steel of 35 to 40 ton characteristics. This steel is standard, easily obtainable, and not costly. The oil toughening process adds 15 per cent. to 20 per cent. to all the useful qualities of the steel; it also induces resilience and springiness, with the result that risk of breakage or fracture is much reduced, and the resultant effect is even better than that obtained by adding 15 per cent. to 20 per cent. to the dimensions of an untreated forging.

Commercial mild steel bar and cold rolled shaft may be used for general purposes providing the conditions are not severe and the working stress low.

Aged second-hand shafting of considerable dimensions should not be used for any purpose other than that of the original design, otherwise the change of duty or reversal of stress will invite early failure. If under emergency conditions it is necessary to re-use any such shaft, it should first be annealed and re-machined, removing as little metal as possible in the process. It is undesirable seriously to reduce the size of any heavy shaft of considerable dimensions, bearing in mind that the strength, closeness of structure, and homogeneity of any forging is nearest the outer surface. Moreover the risk of opening up laminations, etc., is much increased by large diametral reduction.

The forgings for all important new shafts should be in substantial agreement with B.S.S. No. 2 (Report No. 24, Part 1) of 35 to 40 ton limits with an elongation of 25 per cent. to 20 per cent. The yield point ratio should not be less than 50 per cent. and the quality factor not less than 60.

Gearing.

Gearing also plays a very important part owing to the high unit pressures and slow unit speeds now in general use, and as such power is transmitted under vibrating conditions nothing but steel gearing is sufficiently reliable for general use. All gearing should be machine cut unless the duty is light and the speed relatively low. The cost of gear cutting is being continually reduced and the

cost of " gashing " is low ; all pinions, therefore, whatever the size and pitch, should be of forged steel, " gashed " and machine finished in the usual way.

Gear forgings of considerable dimensions should be of 0·45 per cent. to 0·55 per cent. carbon steel, or alternatively 0·40 per cent. to 0·50 per cent. carbon with 0·60 per cent. to 0·75 per cent. manganese and " shorter " hardened after the machining and cutting have been completed. " Shorter " hardening produces a very hard case, up to 0·2in. thick, with a toughened core ; it reduces wear and adds very largely to the working life of a pinion. Moreover, maintaining a correct profile on the pinion teeth enables the correct profile to be maintained on the wheel teeth and the small additional cost incurred in hardening the pinion becomes a distinct advantage to the wheel also.

The gear wheel may be cast or fabricated ; the type selected must be determined by the general design. If the wheel is of " cast " steel it may have a carbon content of 0·45 per cent. to 0·50 per cent. ; an addition of manganese would also prove an advantage. The casting should be subjected to the complete annealing process, that is to say the hardness value of the material should be obtained exclusively by the composition of the metal and not by its heat treatment apart from annealing. The teeth of the wheel need not be hardened, though they could be dealt with in that way if the wheel or rim were fabricated.

The advantage of a fabricated wheel is that more complete homogeneity of the gear rim is obtainable and the metal is more definitely under control ; moreover, the work which results from the various rolling, forging, and hammering processes is of definite value, and risk of ultimate distortion is also much reduced.

If the metal of the pinion and wheel is as described and hardened, and if the gear is enclosed in a dust-tight and oil-tight casing, it should be possible to operate with tooth pressures of 1,000 lb. to 1,100 lb. per inch of width and 1,800 lb. to 2,000 lb. per inch of width for gears having circular pitches of 2½in. to 4in. respectively and operating at pitch-line velocities of 750 feet per minute to, say, 900 feet per minute. If the speed is reduced it will be possible to increase the tooth pressures ; on the other hand, if the speed is increased it will be necessary to reduce the pressures named. Bearings, etc., which support the shafts to which gears loaded in this way are fixed should be very rigid and subjected to the minimum deflection. British Standard Specification No. 436 should govern the conditions of supply or form the basis of design of all spur gears that lend themselves to the application of this specification.

Totally enclosed gear boxes, worm reduction gears, etc., can best be dealt with under the advice of gear makers ; they are of considerable value in obtaining large reductions, and wear and waste are proving to be very small.

Kilns.

The general stress and temperature conditions under which most kilns work and the risk of local distortion owing to hot spots are very searching, and boiler-quality plate (acid process) should be used exclusively for parts subjected

to the most severe conditions. Ship-quality plate may be used for those parts of the shell where the conditions are less severe.

The boiler-quality plate and ship-quality plate should be in substantial agreement with B.S.S. Nos. 14 and 13 respectively. These two specifications are substantially the same, but No. 14 calls for a rather more ductile material for thin plates and rivets.

Where the design is good and the proportions liberal, wear, fracture, and waste of the riding rings and rollers is relatively small, as also is that of the roller axles and driving gears with their shafts.

Steel castings used for riding rings and rollers should be in substantial agreement with B.S.S. No. 10, 1930 (Report No. 24, Part IV) of 35 to 40 tons and 20 per cent. to 15 per cent. characteristics; the quality factor must not be less than 55.

Castings of heat-resisting steel of proved value should be used for nose-ring segments or for renewals at the point where the red-hot clinker is discharged and which is subjected to abrasion and a working temperature of 1,500 deg. F. to 1,800 deg. F. Only a high-quality heat-resisting steel will stand up to these conditions. Castings of similar metal either of steel or iron should also be fitted as liners in the recuperator cylinders and similar parts.

Owing to the high cost of heat-resisting steel there may be a tendency to reduce the sectional dimensions of the castings in an attempt to keep down the weight and cost; this, however, should be done very judiciously, otherwise distortion, owing to light section, will be the result.

Heat-resisting steel has been in process of development for some years and possible users or purchasers should consult well-established steel founders who will probably be able to put forward a proprietary product to meet almost any conditions however severe.

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Plant Developments in the United States.

According to Messrs. R. S. Torgerson and B. Nordberg, writing in *Rock Products*, there are now at least six manufacturers who build mills for direct coal firing of rotary kilns. In the few cases where such equipment has not reduced the coal consumption its installation is said to be justified on the basis of uniform burning and its effect on clinker quality and grindability.

Direct-firing coal mills have likewise been improved. The B. and W. mill, in addition to feed control, has thermostatic control, which ensures constant temperature (and therefore constant volume) of the air going to the pulveriser. This is accomplished by damper control at the cold air inlet. A thermocouple in the hot-air duct leading to the fan actuates a motor which is direct-connected to the damper.

The automatic feeder regulator on this mill facilitates uniform burning of clinker by providing adjustment of the coal feed to meet changing kiln requirements. The feeder regulation is said to respond quickly to changes in size, grindability, or moisture content of the coal and to promote fuel economy by maintaining a constant ratio of coal and air.

A new individual coal mill is in operation at the Kosmos Portland works to fire the kilns and the dryers for stone and shale. This mill grinds coal particles while they are suspended in heated air taken from the kiln hoods and is otherwise operated similarly to other accepted types.

Kiln control equipment such as automatic draught controls, recording radiation pyrometers, and continuous gas analysers are continually playing a greater part in cement manufacture. Better control has enabled some manufacturers to increase kiln speeds.

New kilns continue to be longer than those of a few years ago. The newest kilns of the Lone Star Cement Corporation have restricted calcining zones. The kiln diameters are 11 ft. with a calcining zone 10 ft. in diameter ; these are long kilns and the calcining zone is 155 ft. long. This is contrary to usual practice which has been to enlarge the calcining zone, on the theory of delaying the material at this point. In the case of a long restricted zone this would appear unnecessary, and by restricting the diameter the velocity of the kiln gases must be speeded up and the ratio of material in the kiln area exposed to the gases is increased. Heat transfer is a function of the speed of the incandescent gases as well as of the surface exposed in the kiln. Therefore, the practice may be more correct theoretically than the expanded zone idea in the case of long kilns.

Many cement plants are quenching the hot clinker suddenly, upon discharge from the kiln, to create a brittle or glassy structure which is more grindable and apparently reduces the undesirable influence of free lime and magnesia. This is followed by another cooler to reduce temperatures as far as is practicable, as a pretreatment for grinding.

The Valley Forge Cement Co. has installed coolers of new design for primary and secondary temperature reduction. The coolers are described as movable

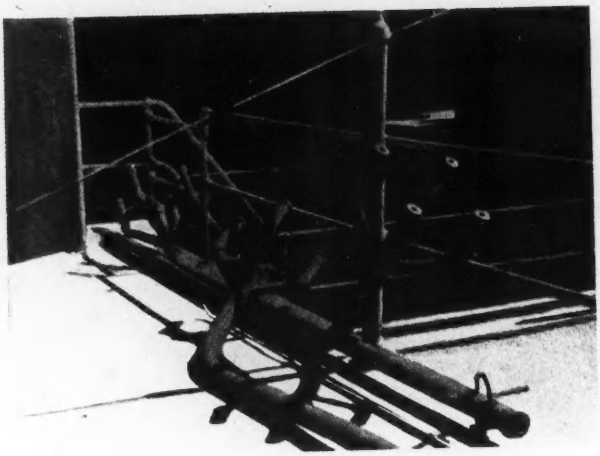


Fig. 1.—Slurry Nozzle (removed from Kiln).

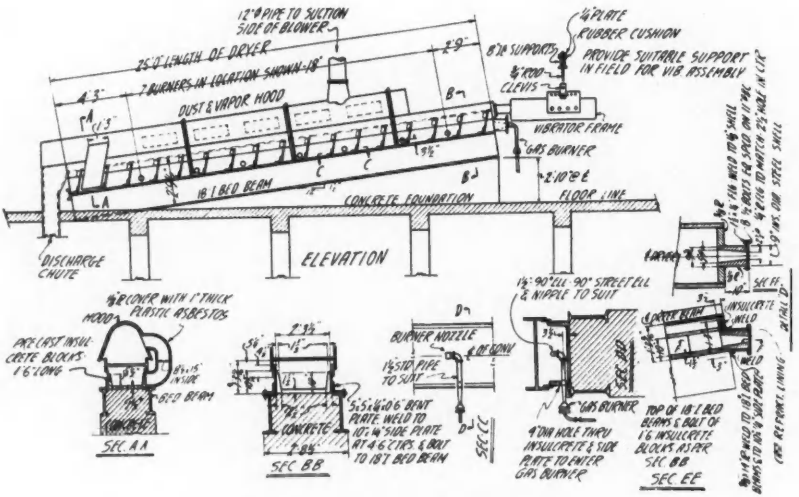


Fig. 2.—A Vibrating Slurry Dryer.

inclined grate coolers, and are of the air-quenching type. Clinker temperatures are reduced from about 2,500 deg. F. to 800-1,200 deg. F. in the first cooler and the product of the second cooler is 120 to 140 deg. F. The arrangement is comparatively simple and occupies very little floor area.

Dryers.

In the raw grinding department of the Universal Atlas Cement Co. the raw materials are dried simultaneously with the pulverising operation, which is done in three mills close-circuited with air separators and bucket elevators. Air, heated by a thermostatically-controlled oil furnace, is introduced through the elevators and into the air separators.

The success of the spray system of slurry feeding apparently depends on several factors among which are: (1) elimination of all coarse particles ahead of the nozzles (to keep them from being plugged); (2) a high pressure pump; (3) adjustment of the spray nozzles to the size of the kiln and other factors of the particular installation; (4) facilities for recovery of stack dust. *Figs.* 1 and 2 show a new type of dryer in operation by the Utah Copper Co. for drying filtered concentrate in the molybdenum recovery plant. This might have possibilities for slurry drying or, by a few changes, for cooling clinker.

Efficiency of Grinding Media

During an extensive investigation of ball-mill grinding made for the United States Bureau of Mines, and reported in Technical Paper No. 581, comparisons were made between tetrahedra and spherical balls, and between spherical balls of different composition. The tetrahedra were all about the same size, and the average weight of each was the same as for a 1⅜-in. spherical ball. Four pairs of tests with tetrahedra and round balls, respectively, were made. The loads weighed 796 lb. each.

In the first pair of tests with chert the tetrahedra were deficient in crushing the coarse particles, and they also failed in capacity and efficiency. In the second pair of tests, when dolomite was ground, the type of grinding was about the same, but otherwise the failure of the tetrahedra was marked. Since the tetrahedra were of one size, it seemed advisable to make further tests and compare them with a load of closely sized balls. Similarly, the ore feed was sized, first + 10-mesh chert and then 28- to 35-mesh chert. The 1⅜-in. balls that were used in the sized-ball load were known to be slightly too small for the coarse charge and too large for the finer charge. The tetrahedra failed on the + 10-mesh charge, and when the finer charge was ground the two media gave the same type of grind; but, as in all the other tests, the tetrahedra failed in both capacity and efficiency.

The keying effects of the tetrahedra against each other is shown by examination of the power records, the tetrahedra requiring about 10 per cent. more power

than the balls. On account of the large area of the plane surfaces exposed to contact, the tetrahedra would possibly serve better for grinding excessively fine material.

Comparison of Types of Balls.

The Carondolet Foundry Co., St. Louis, Mo., supplied 1,000 lb. of 2-in. Ni-hard balls for comparison with balls of other composition. Ni-hard balls are said to contain 2·5 per cent. to 6 per cent. of nickel and 0·5 per cent. to 1·5 per cent. of chromium. Their Brinell hardness is 548. The company also furnished a stock of annealed cast-iron balls. These were very soft (Brinell hardness 150), much of the carbon being in a graphitic state. To the stock were added ordinary cast-iron balls for further comparisons. The three batches of balls were used for comparative grinding tests. In the grinding of chert the Ni-hard balls were superior in every way, the order of decreasing effectiveness being Ni-hard, cast-iron, and annealed cast-iron. In the grinding of the dolomite the Ni-hard balls were superior, but the advantage was not so marked as with the chert.

Examination of the power consumption showed that the annealed cast-iron balls required about 10 per cent. less power than the Ni-hard balls. If they had required more power the possible embedding of the rock particles into their surface would have been offered as an explanation ; but since the power required by the soft cast-iron balls was less, the presence of graphite must be the explanation.

The surface of the annealed cast-iron balls was about 8 per cent. graphite by volume. By acting as a lubricant, the graphite probably caused slipping of the load against the breast of the mill and slipping of the balls among themselves. This action would reduce the power requirement. The annealed balls would have been given the same amount of action as the Ni-hard balls if the mill loaded with the annealed balls had been run a little faster. The extra speed would have compensated for the loss in capacity, but probably not for the loss in efficiency.

With very hard raw materials the Ni-hard balls showed an advantage that should be given consideration. With hard and moderately hard materials some of the energy of soft balls that should go into crushing goes into deformation of the balls. When the raw material is soft, the soft balls are not handicapped so severely.

Control of Combustion in the Rotary Kiln.

In the course of an address to a meeting of the Anthracite-Lehigh Valley Section of the American Society of Mechanical Engineers recently, Professor W. E. Reaser, of Lafayette College, Easton, Penn., dealt with new developments in the cement burning process, from which we take the following:

The movement toward more scientific burning appears to be progressing steadily. A few of the developments, such as the radiation pyrometer, the photo-cell pyrometer, automatic control of draught and air flow, improvements in coal-feeding apparatus which are readily susceptible to control by automatic devices, and improved automatic gas analyses are worthy of attention.

The immediate factors in the burning of the raw material are the size and shape of the kiln, the fuel and air supply, the quality and quantity of the raw material, and the quality and quantity of the discharged clinker. As for the first of these, once a kiln is designed and built, the burner can do nothing about making changes, in the ordinary course of burning clinker, though of course this factor may have a distinct effect on what procedure of operation is finally decided upon. For some time past it has been recognised that it is desirable to have as nearly as possible a constant load in the kiln, a condition aimed at by relating the speed of the kiln with the speed of the raw feed, either by mechanical or electrical means. The limiting element in such a scheme is whether or not there is delivered a positive quantity of material per revolution of the feeder. Though this scheme is not entirely successful, it has eliminated from the hands of the operator one more variable over which he had control. Probably this development has worked more successfully in the wet process than in the dry, because, if the buckets or other device for carrying the slurry to the kiln are cleaned periodically, for all practical purposes a positive quantity of material is delivered to the kiln. In the dry process, however, there is involved the design of the bunker, the condition of the raw feed, and the inherent tendency of such installations to rat-hole or flood. The most important devices required for thoroughly satisfactory kiln operation are feeders which have positive control over the supply of both raw material and coal.

As for maintenance of a constant quality of raw feed, the wet process has advantages over the dry, though generally the burner is not required to "juggle" his kiln in order to overcome variations in the chemical analysis of the material. This problem is far more near a satisfactory solution than is the burning process at the front of the kiln.

Hence, only the proportioning of the fuel and the air, and the burning of the clinker, are to be considered. But although general principles are to be laid down it cannot be too strongly emphasised that each kiln is its own problem and that a thorough study of every installation must be made before any system of operation and control is suggested. However, it is more or less generally agreed that there are two fundamental schemes of handling a rotary kiln:

(1) To operate at a constant speed of kiln and vary the combustion rate, that is, vary the quantity of fuel and air, to maintain the desired temperature in the burning zone.

(2) To operate at as nearly a constant combustion rate as the firing equipment will permit, and vary the speed of the kiln to maintain required burning zone conditions.

The first of these schemes demands an apparatus to show continuously in some fashion the condition of the exit gases in order that, when sufficient fuel is being fired to carry the load, the correct quantity of air is supplied to burn completely all the combustible without having too great an excess of air. An automatic gas analyser, electrically operated, to indicate and record CO_2 and $CO + H_2$ has been used successfully, particularly on long kilns where exit-gas temperatures are comparatively low and the problem of getting the sample of gas is not so

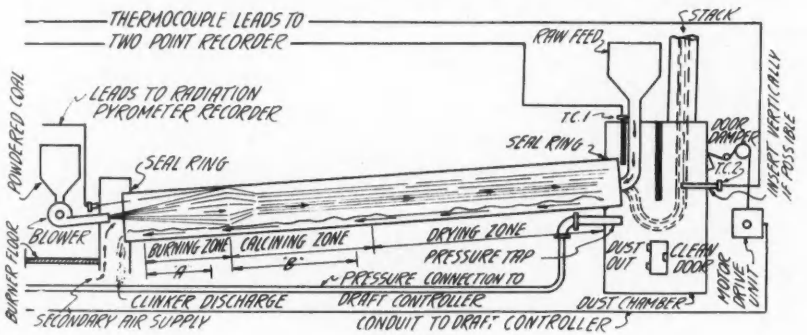


Fig. 1.

difficult as on short kilns where exit-gas temperatures are between 1,300 deg. F. and 1,800 deg. F. The greatest objection is that so far no automatic feature to control the air supply has been applied. A further point is that when the fuel flow is changed it is desirable to change the primary air flow in order that it remain as a constant percentage of the total air required for combustion. Except for one type of firing pulverised coal by means of a unit mill equipped with a special control, there is no means whereby this requirement can be satisfactorily met. The automatic gas analyser, if it operates 100 per cent. efficiently, only shows whether or not there is sufficient total air to burn out the combustible material. There is also a two-point temperature apparatus shown in *Fig.* 1, which has been successfully applied to maintain automatically the desired total air when the combustion rate is either held constant or is varied. It will be noted, however, that there should be sufficient distance between thermo-couples 1 and 2 to give a temperature drop of about 40 deg. or more, and the arrangement should be such that under ordinary operating conditions cleaning doors should not be opened because a variable infiltration of air would upset the control apparatus.

The second scheme of operation is somewhat more susceptible to automatic control. It is possible to apply apparatus to kilns to maintain automatically the necessary air flow and draught conditions, and then adjust the fuel flow until the desired combustion conditions prevail, as shown by a series of gas analyses taken by means of a hand Orsat apparatus. Once having determined the correct fuel flow-air flow relation required to burn the necessary quantity

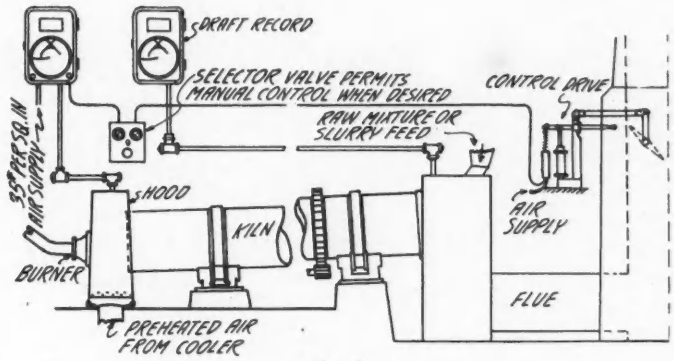


Fig. 2.

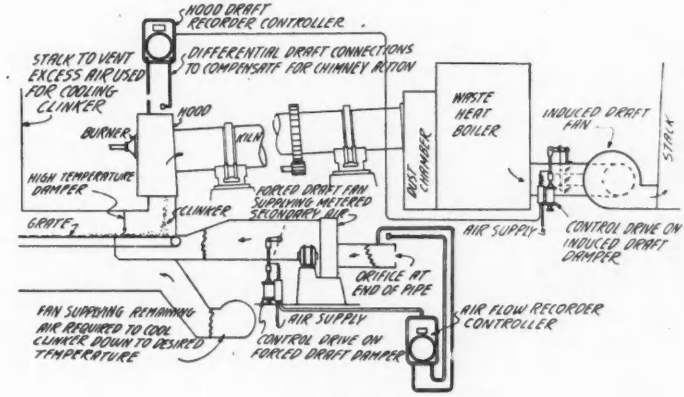


Fig. 3.

of material per hour, within certain limits as governed by the type of fuel feeding apparatus, it is possible to operate at this combustion rate and burn by varying the speed of the kiln.

Fig. **2** shows a scheme for controlling the draught in a kiln where all secondary air is supplied under forced draught. A draught recorder is located at the feed end of the kiln in order that variations in the draught differential across the kiln (probably caused by rings) may be noted.

Fig. 3 gives the arrangement of control for a kiln where the secondary air is supplied under forced draught. An extra fan is indicated if more air is required for cooling the clinker than is required for combustion purposes. In both arrangements it is assumed that the kiln is operated at a constant rate.

When the firing of the fuel is done by an apparatus which will continuously supply practically a weighed quantity of coal, as with a unit mill, and the air-flow is controlled by automatic means, this problem is not so difficult and checking of the settings would not be required at too frequent intervals. However, when the fuel feeder is governed by volumetric measurement and when coal screws are dependent upon the free flow of coal to them from the bunker, precautions have to be taken. Experience has shown that adjustments of the fuel feeder can be made on the basis of daily tests of exit-gas conditions and that, except for unusual circumstances, it is possible to operate with a fixed fuel rheostat between test periods.

Having once put the fuel and air under control, there remains the necessity for controlling the burning to maintain desired temperatures at which to finish

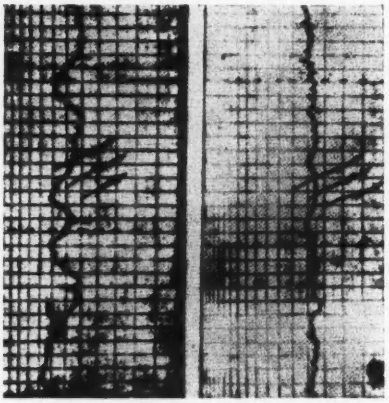


Fig. 4.—Temperature Charts of Burning Zone when radiation pyrometer is used (right) and when it is not used (left).

the clinker. The radiation pyrometer and the electric eye have been used to guide the operator to make hand adjustments of the speed of kiln, or to do this job automatically.

What are some of the results to be expected from a more scientific burning process ?

To name a few : fuel economy ; more constant production ; more even quality of product with consequent effect in the finish-grinding process ; longer life of the refractories ; elimination of secondary combustion and consequent troubles in dust chamber and boiler passages ; elimination of the human element ; and finally, an over-all economy without the necessity of a large capital investment.

Separation of Minerals in Cement Manufacture.

(Continued from February.)

A brief reference to the flow sheet of the processing plant (*Fig.* 3) and a plan (*Fig.* 4) illustrating the arrangement of the principal units of equipment will simplify the description of the functions of the units of the process plant. The overflow of the bowl classifier is sent to 23-ft. by 23-ft. turbo-mixers, shown in the plan, which act as slurry storage tanks and surge tanks to keep the solids in suspension until they are fed to two 45-ft. hydro-separators connected in series.

Substantially all the fine calcium carbonate and the necessary proportions

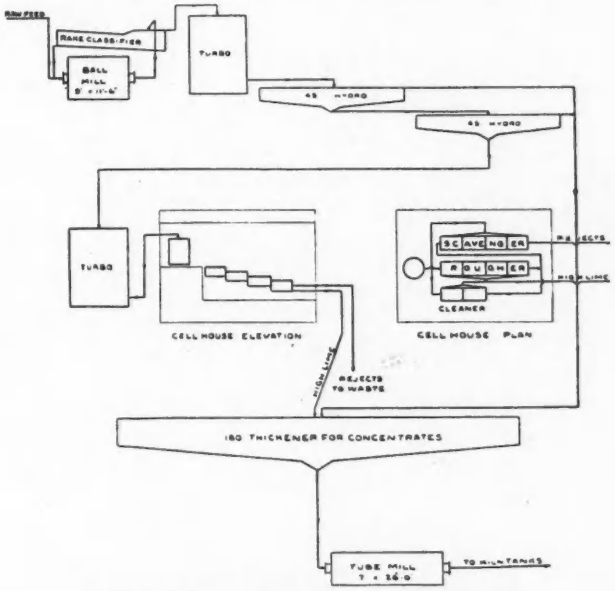


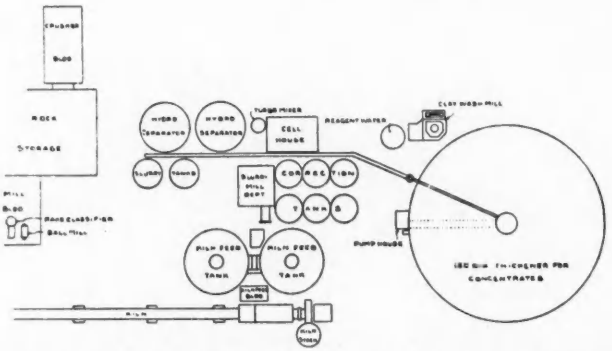
Fig. 3.—Flow Sheet of the Processing Plant.

of the fine clay minerals are recovered as overflow from the two hydro-separators. The underflow from the second hydro-separator is largely calcite and coarse quartz, evidently of sea sand origin, and is fed to the flotation cells where the quartz is rejected and pumped to waste. The calcium carbonate concentrate is fed to a 180-ft. thickener where it joins the fine calcium carbonate and clay minerals, that is, the overflow from the hydro-separators. The mixture, after extraction of the water and grinding in open circuit to proper fineness in a 7-ft. by 26-ft. tube mill, constitutes the kiln feed.

As the proportion of alumina in the natural materials is reduced in the normal operation of the process plant and as there are substantially no undesirable

minerals, other than the excessive proportion of coarse quartz, which occurs widely distributed throughout the deposit, including the clay, the removal of the coarse quartz and the reduction of the silica ratio are the principal functions of the flotation cells.

Hydro-separation of the overflow of the bowl classifier has, accordingly, a number of advantages, both in relation to the chemical characteristics of the composition and the operating economy of the plant. The removal of the fine calcium carbonate and the necessary quantities of clay minerals, as hydro-separator overflow requiring no further treatment than combination with the high-lime concentrates of the flotation cells, limits the quantity of material that must be treated by froth-flotation to make the necessary chemical corrections. Thus, the coarse fractions only, representing from 60 per cent. to 65 per cent. of the total quarried materials, must be treated by flotation, the excessive proportion of quartz being subtracted without wasting the disproportionate amount of grinding power that would be necessary to reduce it to normal kiln-feed fineness. Its removal prior to final grinding has obvious advantages in mill economy. As the coarse product, forming the underflow of the second hydro-


CRUSHER
ROCK
STORAGE
HYDRO SEPARATOR
HYDRO SEPARATOR
CELL HOUSE
REAGENT WATER
CLAY WASH MILL
FLOTATION
TANKS
FLOTATION
CELL
FLOTATION
CELL
FLOTATION
CELL

The average analyses of the feed and classifier products are as follows :

Chemical Analyses of the Feed and Classifier Products.

	Hydro-separator feed	Hydro No. 1 overflow	Hydro. No. 2 overflow	Cell feed
SiO_2	28·70	24·00	24·64	30·83
Re_2O_3	2·57	2·95	2·75	2·36
Al_2O_3	4·01	5·93	5·97	2·92
CaO	33·35	33·32	32·52	33·52
$CaCO_3$	59·50	59·48	58·08	59·85
MgO	1·25	1·78	2·03	0·90
Loss	29·69	31·46	31·24	28·72
Total	99·55	99·44	99·15	99·30
Ratio SiO_2/R_2O_3	4·36	2·70	2·82	5·85

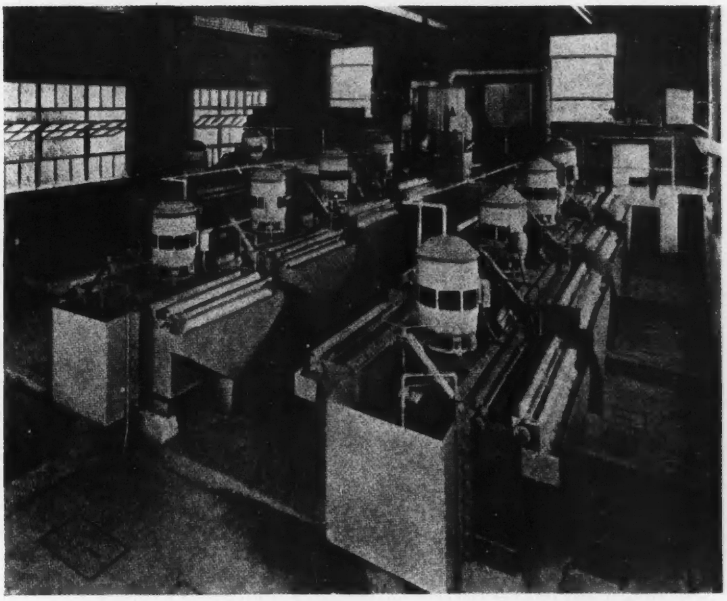


Fig. 5.—View inside Cell House showing Scavenger Cells on the right, Rougher Cells in the middle, and Cleaner Cells on the left.

The principal equipment of the cell house consists of a turbo-mixer, used for a surge tank and storage, an agitated feed tank, and ten flotation cells.

The grade of the flotation concentrates and the weight recoveries are under complete control and are kept uniform, so that by properly proportioning the tonnage fed to the flotation cells with relation to the hydro-separator overflow, inversely as the $CaCO_3$ content of the quarried material changes, the mixture

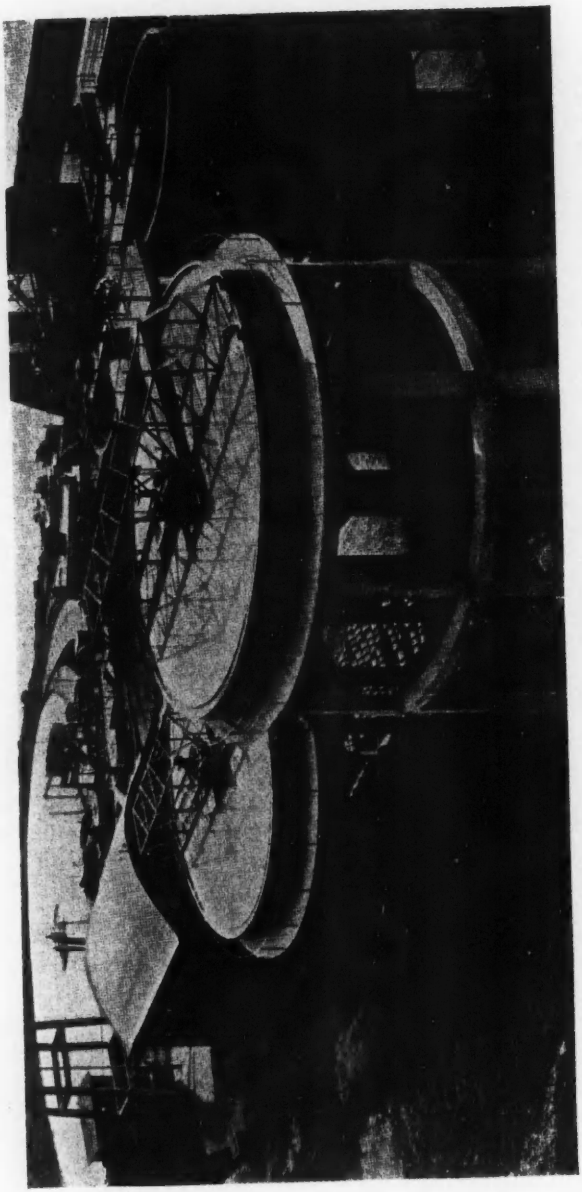


Fig. 6.—Flotation Plant with Two Hydraulic Separators in the foreground, and the Cell House and 180-ft. Thickener at the back.

of the overflow with the concentrates in the thickener is maintained at the desired kiln-feed composition. Operated in this manner, the process plant serves to produce a continuously corrected kiln feed, thoroughly mixed and blended by the natural action of the thickener prior to final grinding. The principal flotation control is effected by feeding the proper quantity of calcite collecting reagent to each cell of the flotation circuit, each cell being equipped with an adjustable reagent feeder.

Recent Patents Relating to Cement and Lime.

Porous Compositions : Concrete and Rotary Furnaces.

491,339. E. I. Lindman. June 14, 1937.

FIG. 1.

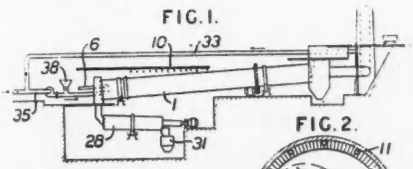
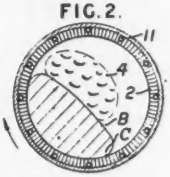


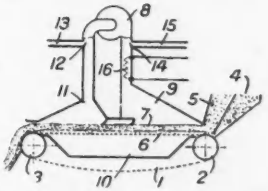
FIG. 2.



Cellular clinker - like material, which may be used as an aggregate in light-weight concrete, is made by melting or burning to a viscous melting state rocks or clay or both, which are expanded by gases enclosed or evolved therein, in a rotary or rocking furnace by flames burning above the rocks, etc., the inner wall of the furnace having a coefficient of heat transmission substantially higher than that of the expanded mass, while in the expansion zone during expansion the surface of the mass is cooled at that part which at each moment is in contact or about to make contact with the furnace wall due to the rolling motion of the furnace, whereby the mass is prevented from sticking to the wall.

The rocks, etc., may be of eruptive or igneous origin, e.g. basalt, diabase, granite, schists or slates. Quaternary clay is passed through a rotary furnace (1) lined with chamotte, (2), and burnt therein by gas, oil or pulverised coal flames from burners (6). The surface B—C of the charge is cooled (*a*) by radiation of heat to the chamotte, which is cooled by coils (11) and by water sprayed from pipes (10) on to the furnace shell, and (*b*) by cold air or other gas injected through a pipe (35) between the flames (4) and the chamotte lining. At (38) finely-divided cold raw material, similar to or different from the main charge, is introduced. The heat absorbed by the cold air, etc., preheats the raw material in the upper part of the furnace. Products of combustion are returned to pipe (35) via pipe (33). The product is cooled in a drum (28) and crushed at (31).

491,877. N. Ahlmann. March 11, 1937.



Cement raw materials are sintered by forming a porous layer of fine granules of the raw material on a gas-permeable support and passing gases at a temperature equal or substantially equal to the sintering temperature, i.e., about 1,400 to 1,500 deg. C., through the layer. The raw material may be made porous as described in Specification 407,077; the average size of the granules should be about 1 mm. in diameter and should not exceed 3 mm. The raw materials may be preheated and even substantially calcined by mixing them with fuel, igniting and drawing air therethrough to effect combustion. The heating gases may be continuously circulated through the

layer of raw material and reheated, e.g., electrically and/or by mixing with hot furnace gases; a fraction of the gases may be continuously bled off and carbon dioxide isolated therefrom.

In the apparatus shown, two hoppers (4, 5) respectively supply a heat resistant material such as clinker and raw material to form layers (6) and (7) on a chain grate (1) moving around rollers (2, 3). The hot gases are circulated by a fan (8) and, after being heated by an electric furnace (16), pass first into a hood (9), then through the layers (7, 6) and the grate (1) into a space (10) which is sealed relatively to the grate (1), thence they pass upwards through the grate and layers (6, 7) to a pipe (11) connected to the suction side of the fan (8). Additional gases may be admitted through a pipe (13) having an adjustable damper (12) and gases may be removed through a pipe (15) having an adjustable damper (14).

Portland Cement.

494,891. O. Schwachheim. May 19, 1938.

White cement is obtained by mixing chloride of lime with the cement raw materials, heating the mixture in a reducing atmosphere until sintering occurs, and cooling with the exclusion of air. The raw materials may be pretreated with chlorine to form the chloride of lime in situ. A flux such as fluorspar may be added. Part of the chloride of lime may be replaced by selenium, in which case alkali chlorides may also be added.

Refractory Substances.

492,718. J. Robinson. March 24, 1937.

Semi-permanent moulds and cores are made wholly or in part from aluminous hydraulic cement, free from metallic oxides and containing lime 42 per cent., alumina 48 per cent. or over, and less than 7 per cent. of silica, mixed with graphite or other refractory form of carbon. One part of cement is mixed with three parts of carbon, or some of the carbon is replaced by refractory material such as aggregate, broken old moulds, or kyanite. The water used should be insufficient to hydrate the cement wholly. The moulds may be dried up to 600 deg. C. The first provisional specification describes moulds made without graphite or carbon, and the second provisional specification describes material in which the cement used contains iron, titanium, or other oxides and the use of material for making crucibles, cupels, melting-pots, nozzles, stoppers, etc., used in melting metal, glass, or the like.

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SAUNDERS VALVES.

A new factory, costing £100,000 and giving employment to 150 men, has been built at Cwmbran by the Cwmbran Engineering Co. (a subsidiary company of the Saunders Valve Co.) for the production of the well-known Saunders valves. The smaller valves are already being made at the new factory, and ultimately the production of all sizes of valves will be transferred from Wolverhampton to Cwmbran. The popularity of this valve is shown by the fact that more than 800,000 of the streamline diaphragm type have been installed throughout the world during the past few years. The newer " Straightway " valve is meeting with similar success for dealing with high velocities and viscosities.

Decrease in Fuel Consumption in Cement Manufacture.

A REPORT made by Mr. P. M. Tyler to the U.S. Bureau of Mines states that the average consumption of energy at the cement plants in the United States declined from 189 lb. of coal equivalent per barrel of cement in 1914 to 159 lb. in 1935. The gain in fuel economy has been less in the cement industry than in other and more important fuel-consuming industries, notably in electric power stations and steam locomotives, but the saving in the cement industry is significant because fuel is so important a factor in the cost of manufacture. In 1914 the cost of fuels and purchased electric energy represented 24·7 per cent. of the total value of cement, f.o.b. plant; in 1935 it was 19·4 per cent. It is still a larger factor than wages, because labour cost also declined, the corresponding percentages of the value of cement being 22·1 and 17·9 for the respective years (compared with 33·9 per cent. in 1904). In 1935 the average labour cost of a barrel of cement (direct wages) was about 26·9 cents, and the expenditure for energy was 29·3 cents. Continued progress in fuel efficiency in cement making is expected for at least another decade, as new improvements are adopted and as equipment already successfully applied is used more extensively.

Wet and Dry Plants Compared.

In recent years the principal gains have occurred in the wet-process plants, which show a decline of 18·5 per cent. between 1927 and 1935. In 1927 wet-process plants contributed only 34·1 per cent. to the national output; but in 1935 this figure had risen to 52 per cent. Whereas in 1927 the wet-process plants consumed about 24·4 lb. more coal or equivalent fuel, oil, or electric power per barrel of cement than dry-process plants, by 1935 their fuel consumption had dropped to about 5 lb. below that of dry-process plants.

The greatest progress in fuel economy has occurred at plants burning liquid and gaseous fuel. From 1927 to 1935 plants burning principally oil or natural gas showed a reduction of their unit fuel requirement of 21 and 22 per cent. respectively, compared with a decline of only 7 per cent. at coal-burning plants. Over this period the oil-burning plants showed the lowest average rate of consumption per barrel of cement (118·2 lb. of coal equivalent); gas-burning plants had the highest consumption (143·6 lb.); and coal-burning plants consumed 132·3 lb. Until 1919 at least 80 per cent. of the total energy consumption of cement plants was in the form of bituminous coal, but in 1935 coal contributed only 65 per cent., natural gas about 20 per cent., purchased electricity (used for power, etc.) over 10 per cent., and oil 5 per cent.

A joint report prepared by the Works Progress Administration in co-operation with the Bureau of Mines (" Fuel Efficiency in Cement Manufacture," 1909-1935) analyses these changes and discusses the various factors that affect fuel economy, such as wet- versus dry-processes, larger kilns, slurry filters, slurry chains, methods of using the sensible heat left in clinker and reducing radiation losses.

Other Possibilities in Saving Fuel.

In the report suggestions towards further technological improvements that would permit still further economy in fuel consumption in the cement industry were made. Among the possibilities in this direction is the suggestion by Newhouse that some of the heat radiated from the kiln shell might be recovered by building a stationary jacket around the kiln at the hot zone and drawing air through the intervening space. This preheated air might then be used for drying coal or as primary air for combustion in the kiln. The idea has also been advanced that the efficiency of kilns could be increased by feeding some of the fuel directly into the calcining zone of the kiln, and a patent has been granted on a device designed to accomplish this.

At one dry-process cement plant in the United States the hot kiln exit gases are used to preheat the raw mix. The dry pulverised raw material is pumped through many lengths of pipes enclosed in a chamber through which the hot kiln gases pass. The pumping power required is reported to be small, for expansion of the air and raw material mixture in the pipes facilitates movement. Hot kiln gases may also be used more widely to evaporate the moisture in the slurry at wet-process plants by spraying the slurry into the kiln through nozzles. In this arrangement the finely divided slurry is brought into contact with the kiln gases at high velocity, and a greater surface exposure results in an effective heat transfer. Swedish and Belgian plants that have used this system report a 20 per cent. reduction in fuel consumption, and the method has been adopted by at least one plant in the United States.

Other fuel savings will doubtless accompany technical changes that bring better control and uniformity in kiln operating conditions, especially in the control of raw mix, fuel, and air supply. If more Portland blast-furnace cement is made the fuel requirements of the industry will be lowered, since this material requires less heat for calcining and clinkering than the usual raw materials.

THE NEW FACTORIES ACT.—Messrs. Davidson & Co., Ltd., of Sirocco Engineering Works, Belfast, have issued an interesting and useful brochure dealing with the new Factories Act. This brochure, which will be sent on application to those interested, gives much useful memoranda on the sections of the Act relating to temperature, ventilation, and the removal of dust and fumes.

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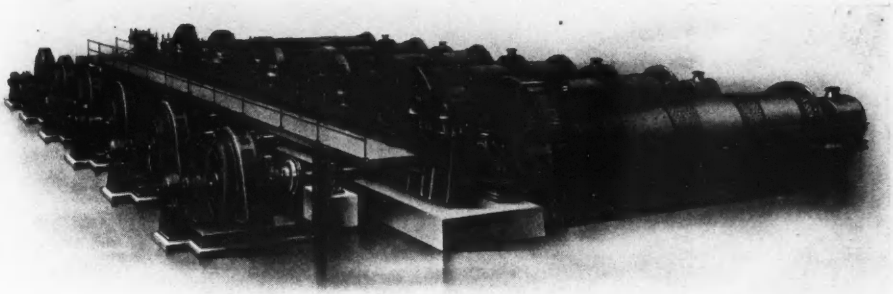

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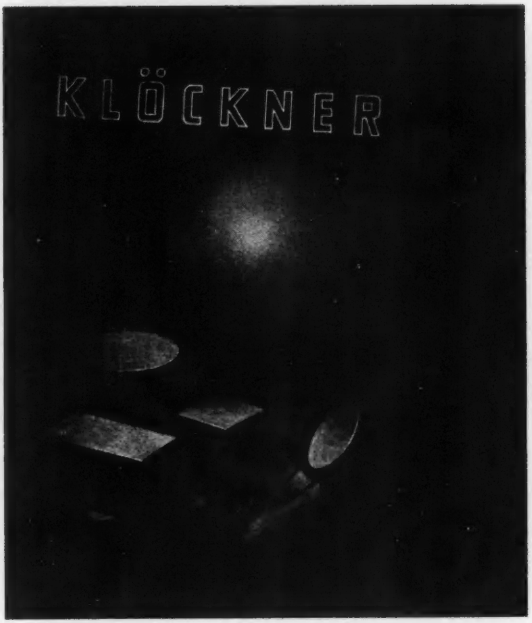

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